



BURNING, TILLAGE AND HERBICIDE EFFECTS ON THE SOIL MICROFLORA IN A WHEAT-SOYBEAN DOUBLE-CROP SYSTEM

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Summary—As sustainable crop management systems are developed, an assessment of the effects of these practices on the soil microflora is essential to ensure maximum productivity. A 3-year field study was established to determine the effects of crop residue burning, no-till management and four preemergence herbicides on soil microorganisms. Numbers of actinomycetes, algae, bacteria, fungi and nitrifiers were evaluated during the soybean [*Glycine max* (L.) Merrill] growing season in a wheat (*Triticum aestivum* L.)–soybean double-cropping system. Residue burning and tillage had no effect on numbers of bacteria and nitrifiers. Non-disturbed (non-burned or no-till) plots had greater numbers of actinomycetes, algae and fungi 7 days after herbicide application each year, but the increases generally did not persist through the season. Herbicide application had no effect on microbial numbers. This is particularly important with recent increased emphasis on protection of soil and water resources from pesticide contamination. As new management systems are developed, their effects on biological properties must be carefully assessed, since the soil microflora play such a vital role.

INTRODUCTION

Sustainable agricultural systems that require minimal inputs yet provide maximum profit for the producer are being developed across the U.S. Recent projections indicate that conservation tillage will be practiced on 63–82% of total U.S. cropland by the year 2010 (Schertz, 1988).

Minimum- and no-till cropping systems are key components in long-term, sustainable systems. At several sites in the U.S.A., numbers of major groups of microorganisms (fungi, actinomycetes, aerobic bacteria, nitrifiers and denitrifiers) were greater in no-till than in conventional-till systems at the 0–7.5 cm depth, and the reverse was usually true at the 7.5–15 cm depth (Doran, 1980, 1987). Similar results were reported for long-term, no-till plots in Kentucky (Smith and Rice, 1983).

Surface crop residues in no-till systems can intercept herbicides and decrease efficacy (Sanford, 1982). Changes in microbial activity during burning depend on soil temperature, length of burning, postfire rainfall, type of microorganism and time of sampling (Ahlgren, 1974).

In a review in 1978, Anderson concluded that very

few herbicides have any prolonged adverse effect on soil bacteria. Variability in herbicidal effects have been attributed to soil type, soil moisture, temperature, pH, nutrient availability and many other factors (Smith, 1982).

As greater emphasis is placed on developing more sustainable methods of crop production, it is important to evaluate the effect of these management practices on the soil microflora. This 3-year field study was established to determine the effects of crop residue burning, no-till management and four pre-emergence herbicides on the soil microflora.

MATERIALS AND METHODS

The study began in the fall of 1982 at the Southern Piedmont Conservation Research Center (USDA-ARS) near Watkinsville, GA. Microbial communities were evaluated in 1983, 1984 and 1985 during the soybean season in a wheat–soybean double-cropping system. The area was planted in a wheat–no-till soybean rotation during 1980 and 1981. The soil series is a Cecil sandy loam (clayey, kaolinitic, thermic, Typic Hapludult) with an average pH of 5.6. Organic matter content averaged 43, 38 and 38 Mg ha⁻¹ in 1983, 1984 and 1985, respectively, and amounts did not differ among treatments.

The plots were disked (15 cm) each fall and seeded to soft red winter wheat ("Omega 78"). Each October, plots were fertilized with 56, 49 and 140 kg ha⁻¹ of N, P and K, respectively. In early March, the wheat received 56 kg ha⁻¹ of N as NH₄NO₃. Wheat

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was harvested in the third week of June, and the amount of straw remaining was 3360 kg ha⁻¹ in 1983, 9500 kg ha⁻¹ in 1984 and 4700 kg ha⁻¹ in 1985.

A strip-split plot design with four replications was the experimental design during the soybean season. Burning or non-burning of wheat straw before soybean planting were main plots, and conventional- or no-till were sub-plots applied in strips across main plots. Tilled plots were plowed (15–20 cm) with a heavy-duty double disk and seeded with an in-row chisel with a fluted coulter. No-till soybeans were planted with a no-till planter with a fluted coulter. "Ransom" soybeans were planted (26–30 seed m⁻²) in four 8-m rows (spaced 76 cm apart) in the third week of June.

The sub-sub-plots were four herbicides registered for use in soybeans: metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide], metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)one], norflurazon [4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3(2*H*)pyridazinone] and oryzalin [4-(dipropylamino)-3,5-dinitrobenzenesulfonamide] at rates of 2.24, 0.43, 1.40 and 1.12 kg a.i. ha⁻¹, respectively. Control sub-sub-plots without herbicide treatment were also included. Herbicides were applied within 24 h of planting with a tractor-mounted, CO₂-pressurized sprayer with a carrier volume of 280 l. H₂O ha⁻¹. All treatments were on the same plots each year.

Numbers of microorganisms were evaluated 7, 30 and 80 days following herbicide application. Six soil samples were taken at two depths (0–2 and 2–15 cm) from each plot with a 2.5 cm dia soil probe. Soil samples from replications 1 and 3 were combined as were samples from replications 2 and 4, and combined samples were mixed thoroughly.

Microbial analyses began 3 h after sampling. Sub-samples (10 g) were placed in 90 ml of sterile H₂O, shaken for 15 min on a reciprocating shaker, and diluted to 10⁻⁶ in sterile H₂O. Counts for actinomycetes, bacteria and fungi were made using a modified soil dilution plating method on caseinate agar, soil extract agar and rose Bengal agar supplemented with streptomycin (30 µg ml⁻¹), respectively (Wollum, 1982). Numbers of microorganisms were determined after incubation at 22–25°C for 3, 5 and 10 days for fungi, bacteria and actinomycetes, respectively. Algal numbers were determined only for the 0–2 cm soil depth by the most-probable-number (MPN) technique (Alexander, 1982). Numbers of nitrifiers were determined using a chlorate inhibition method (Belser and Mays, 1980). Nitrite concentrations were determined with a colorimeter and used to calculate numbers of nitrifiers (Schmidt and Belser, 1982).

Log-transformed data were subject to analysis of variance to determine burning, tillage, herbicide and sampling date effects on microbial numbers using the ANOVA procedure of the Statistical Analysis System

(SAS; Helwig and Council, 1979). All microbial data are presented on a volume basis using bulk density measurements of tilled and no-tilled soils at an adjacent site (Bruce *et al.*, 1990). The initial analysis showed that sampling depth and year were significant. Therefore, the data were analyzed by year and depth as a split, split, split-plot analysis. Sampling date was the first split, burning was the second split, tillage was the third split and herbicide treatment was the fourth split.

Analysis by year indicated that sampling date interactions with other effects were predominant for most microbial communities. A subsequent analysis was performed by date to evaluate specific effects. Herbicides were used as replications at this point because herbicide treatment was not significant in previous analyses.

A significance level of 0.01 was chosen so that meaningful differences were evaluated. When main or interaction effects were significant, LSD values were calculated at *P* = 0.01. The interaction LSD values were calculated according to Gomez and Gomez (1984) for a split-plot analysis.

RESULTS

Since initial data analyses indicated that sampling year and date were significant, all analyses are reported by year and date. No differences due to treatment were observed at the second depth, so discussion will be limited to samples taken from the 0–2 cm depth.

None of the herbicides affected total microbial numbers either immediately after application or after 80 days (data not shown). Microbial communities tended to increase between 7 and 30 days after herbicide application, then stabilize between days 30 and 80. Since the increase was consistent across treatments and appeared to be a function of temperature and moisture, microbial changes across time were not considered. Herbicide-treated plots were used as additional replications in subsequent data analyses since application was not significant.

Burning and tillage had no significant effect on numbers of bacteria or nitrifiers on any sampling date. Numbers of bacteria averaged 3.4×10^7 , 4.4×10^7 and 1.9×10^7 cfu cm⁻³ in 1983, 1984 and 1985, respectively. Nitrifiers averaged 2.7×10^4 cfu cm⁻³ in 1984 and 2.8×10^5 cfu cm⁻³ in 1985. Data for 1983 are not reported due to processing errors.

Numbers of actinomycetes were greater in no-till plots than in tilled plots on day 7 in 1983, but tilled plots contained greater numbers on the same date in 1984 (Table 1). This was the only time when numbers of any microbial group were greater in the tilled plots. Numbers of actinomycetes were greater in non-burned plots than in burned plots on day 7 in 1984 and day 80 in 1984 and 1985. Also, there was a significant interaction between burning and tillage on day 7 in 1985, where non-burned–no-till plots had

Table 1. Burning and tillage influences on actinomycetes for three dates in 1983, 1984 and 1985

Treatment	Days after planting, 1983			Days after planting, 1984			Days after planting, 1985		
	7	30	80	7	30	80	7	30	80
	Log No. cfu								
Burn-no-till	7.53	6.52	6.61	5.53	6.48	6.10	6.50	6.67	6.67
Burn-till	7.52	6.54	6.71	6.09	6.66	6.20	6.76	6.79	6.79
No-burn-no-till	7.59	6.54	6.82	6.04	6.59	6.31	6.77	6.83	6.95
No-burn-till	7.51	6.86	6.80	6.12	6.45	6.23	6.58	6.89	6.94
LSD*									
Burn	NS	NS	NS	0.26	NS	0.07	NS	NS	0.18
Tillage	0.04	NS	NS	0.29	NS	NS	NS	NS	NS
Burn × Tillage	NS	NS	NS	NS	NS	NS	0.27	NS	NS

*LSD ($P = 0.01$) values for Burn and Tillage are for comparison of main effect means; LSD values for Burn × Tillage are for comparison of interaction means.

greater numbers of actinomycetes than burned-no-till plots.

In 1983, numbers of algae were greater in no-till plots than in tilled plots 7 days after herbicide application (Table 2). Non-burned plots had greater algal numbers than burned plots on day 30 in 1983 and day 7 in 1984. Differences were not observed on any other date. In all cases, numbers of algae were similar in all treatments by day 80 each year.

In general, fungi responded similarly to burning and tillage treatments in 1983, 1984 and 1985 (Table 3). Significantly greater numbers of fungi were present in no-till plots than in tilled plots on days 7 and 80 in 1983 and day 30 in 1984, with no differences observed in 1985. Fungal numbers were greater in non-burned plots than in burned plots on day 7 in 1983 and 1985. In all cases where significant interactions were noted in 1983 and 1984, non-burned-no-till plots contained the greatest numbers of fungi. In general, fungal numbers were similar in all treatments by day 80 each year.

Although burning or tillage altered microbial communities on a specific date, overall trends indicated that treatments did not have a long-term effect on any microbial group. In addition, differences were very small when indicated by analyses (<0.2 log units in many cases). Although significantly different, the changes are not likely to influence soil quality or long-term sustainability.

DISCUSSION

The herbicides had no effect at any time on the soil microflora. Metolachlor and metribuzin are relatively

non-persistent in soil (Bouchard *et al.*, 1982), while norflurazon and oryzalin are relatively persistent (Nelson *et al.*, 1983). Seven days after treatment, the herbicides were readily detected in plots (Banks and Robinson, 1985) but had little effect on the microorganisms. Norflurazon and oryzalin were detected at 160 days, but microbial numbers remained similar. Our results add to the conclusions of Anderson (1978) and Moorman and Dowler (1991) that few herbicides have any lasting effect on soil microflora when applied at field rates.

Although tillage altered numbers of actinomycetes, algae and fungi, numbers were similar in no-till and tilled plots by Day 80. Similar results were reported by Fairchild and Staley (1979). In contrast, Doran (1980) found that microbial numbers were greater in the top 0–7.5 cm of no-till soils than in tilled soils. Our results may differ from those of Doran because our plots were no-till only during the soybean seasons. Plots were disked before wheat planting, therefore, no-till effects may not be readily apparent.

Crop residue burning had only temporary effects on the soil microflora. Little is known about the effects of burning on soil microorganisms in cropping situations, and that information is contradictory. For example, Jorgensen and Hodges (1970) found that bacterial numbers in upper soil layers were greater after burning, but decreases in bacterial numbers have been noted (Wright and Bollen, 1961). In addition, studies have shown decreases (Wright and Tarrant, 1957) and increases (Cohen, 1950) in fungal numbers after burning. However, most of these studies noted only short-term changes.

Table 2. Burning and tillage influences on algae for three dates in 1983, 1984 and 1985

Treatment	Days after planting, 1983			Days after planting, 1984			Days after planting, 1985		
	7	30	80	7	30	80	7	30	80
	Log No. cfu								
Burn-no-till	4.43	4.92	5.62	3.50	4.42	5.24	4.39	5.00	4.70
Burn-till	4.07	5.05	5.36	3.42	5.12	5.38	3.89	5.11	5.17
No-burn-no-till	5.02	5.30	5.26	4.44	5.08	5.11	3.78	5.34	4.91
No-burn-till	4.04	5.13	5.27	4.08	4.97	5.39	3.97	4.91	4.96
LSD*									
Burn	NS	0.21	NS	0.72	NS	NS	NS	NS	NS
Tillage	0.40	NS	NS	NS	NS	NS	NS	NS	NS
Burn × Tillage	NS	NS	NS	NS	NS	NS	NS	NS	NS

*LSD ($P = 0.01$) values for Burn and Tillage are for comparison of main effect means; LSD values for Burn × Tillage are for comparison of interaction means.

Table 3. Burning and tillage influences on fungi for three dates in 1983, 1984 and 1985

Treatment	Days after planting, 1983			Days after planting, 1984			Days after planting, 1985		
	7	30	80	7	30	80	7	30	80
	Log No. cfu								
Burn-no-till	4.98	5.55	5.75	5.17	5.45	5.11	4.95	5.08	5.36
Burn-till	5.01	5.40	5.62	5.35	5.02	5.13	4.83	5.02	5.27
No-burn-no-till	5.45	5.62	5.67	5.54	5.03	5.22	5.17	5.11	5.63
No-burn-till	5.13	5.46	5.66	5.27	4.94	5.13	5.18	5.17	5.61
LSD*									
Burn	0.11	NS	NS	NS	NS	NS	0.12	NS	NS
Tillage	0.11	NS	0.05	NS	0.25	NS	NS	NS	NS
Burn × Tillage	0.16	NS	0.13	0.30	NS	NS	NS	NS	NS

*LSD ($P = 0.01$) values for Burn and Tillage are for comparison of main effect means; LSD values for Burn × Tillage are for comparison of interaction means.

Rainfall patterns after initial treatment varied each year. In 1983, 4.6 cm of rain fell within 48 h after plot establishment, whereas plots received about 2.5 cm in 72 h in 1984. No precipitation was received in the first 96 h after treatment in 1985. Since microbial communities responded similarly to treatments each year, microbial responses did not appear to be linked to rainfall.

Although some microbial groups were affected by crop residue burning or tillage, effects were apparently temporary. In addition, the herbicides had minimal effect on microbial communities. This is particularly important since concerns about adverse effects of herbicides have escalated in recent years. Crop management systems similar to those in our study probably have few lasting effects on major groups of soil microorganisms.

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